SPARTAN 201-03

MISSION REPORT

July 7, 1996

Submitted by

Craig Tooley
Spartan 201 Mission Manager

GSFC Special Payloads Division CM # SPTN-OPS-006

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Introduction:

This report summarizes the flight performance of the Spartan 201-03 payload flown on Space Shuttle flight STS-69. Science instrument performance, spacecraft subsystem performance, and flight anomalies are briefly discussed. Additional references, both specific to this flight and in general, are provided for the science program and the Spartan carrier spacecraft.

Mission Overview & Synopsis:

Spartan 201 is a Solar Physics Spacecraft designed to perform remote sensing of the hot (> 10^6 K) outer layers of the sun's atmosphere or corona. The objective of the observations is to investigate the mechanisms causing the heating of the solar corona and the acceleration of the solar wind which originates in the corona. The third Spartan 201 mission, SP201-03, was coordinated with the passage of the Ulysses spacecraft over the north solar pole. Ulysses is an ESA deep space solar physics spacecraft launched in 1990 which performs in-situ measurements of the solar wind. The previous observations of Spartan 201 during its second flight in September 1994 were coordinated with the Ulysses Spacecraft's south polar pass over the sun.

Spartan 201 carries a pair of complementary instruments which perform co-registered observations of the sun's corona: The Smithsonian Astrophysical Observatory (SAO) Ultraviolet Coronal Spectrometer (UVCS) and the Goddard Space Flight Center (GSFC)/High Altitude Observatory (HAO) White Light Coronagraph (WLC). The instruments are mated and co-aligned inside the SP201 Instrument Carrier (IC).

The WLC (1.25-6.00 R_{solar}) is an externally occulted coronagraph which images the white light corona and provides measurements of the intensity, brightness, polarized brightness and degree of polarization of the electron scattered coronal white light. The measurements allow determination of electron densities in the coronal features observed.

The UVCS (1.35-3.52 R_{solar}) performs spectroscopic measurements of hydrogen Lyman-alpha and oxygen VI spectral lines. The measurements will be used to determine velocities, temperatures and densities of the coronal plasma in the regions observed.

Together the Spartan 201 instruments provide a means of determining physical conditions in our sun's corona by remote sensing methods. The previous two flights of Spartan 201 were extremely successful in advancing our understanding of the solar winds and its origins in the corona. The Spartan 201-02 and 201-03 results will be combined with the Ulysses in-situ measurements over the poles of the sun to continue to develop a much more complete description of the origin of the solar wind than currently exists.

The SP201-03 mission was a scientific and engineering success. The scientific return was only slightly impacted by the spacecraft anomalies described later in this report.

A fourth flight of SP201 is planned for 1997. In addition to the investigation of the physical conditions of the corona at or slightly prior to the rise of the next sunspot cycle, the experiments will be operated simultaneously with the instruments on the Solar and Heliospheric Observatory (SOHO) spacecraft[15] so as to provide additional calibration data for the coronal experiments on-board that satellite.

The Spartan 201-03 payload is shown in figure 1 and the free-flyer SP201 spacecraft in figure 2. More information about Spartan 201 and the Spartan program in general can be found in the references[1,2,3,4,13,14].

Spartan 201 Mission Chronology:

Mission/Flight	Objective	Status
Spartan 201-01/STS-56	Solar Physics	Flown 4/93
Spartan 201-02/STS-64	Solar Physics/Ulysses South Polar Pass	Flown 9/94
Spartan 201-03/STS-69	Solar Physics/Ulysses North Polar Pass	Flown 9/95
Spartan 201-04/STS-87	Solar Physics/Secondary Exp.& SOHO Calibration	Planned 10/97

SP201-03 Mission Summary:

Shuttle Mission:	STS-69 on OV-105/Endeavour
Launch Date/Time:	September 6, 1995 @ 10:09 CDT (MET=0)
Landing Date/Time:	September 18, 1995 @ 6:38 CDT
Altitude/Inclination:	200 n.m./ 28.45 degrees
Bay Location/Orientation	Bay 4/ Y Guides Forward (X_0 = 774.00)

SP201-03 Summary Timeline:

	Orbiter MET:	Spartan MET:
Remote Adjust Angles input	0/21:25:00	
Deploy (RMS D1)	1/00:33:25	0/00:00:00
Pirouette Maneuver		0/00:02:33
Begin Solar Observations		0/01:31:35
* Tape Recorder Shutdown		1/15:46:21
End Of Mission (EOM)		1/19:30:00
* Initiation of Safe Hold (MRS)		1/19:31:30
Visual sighting by crew (61K ft.)	2/21:20:00	
Retrieval (RMS R3)		1/23:20:12
Re-berth in REM	3/00:14:00	

* indicates anomaly

Science Objectives & Instrument Performance:

The performance of the two science instruments is summarized in the following sections. They are edited versions of the summaries[5,6] supplied to the Spartan project by the science teams after the mission.

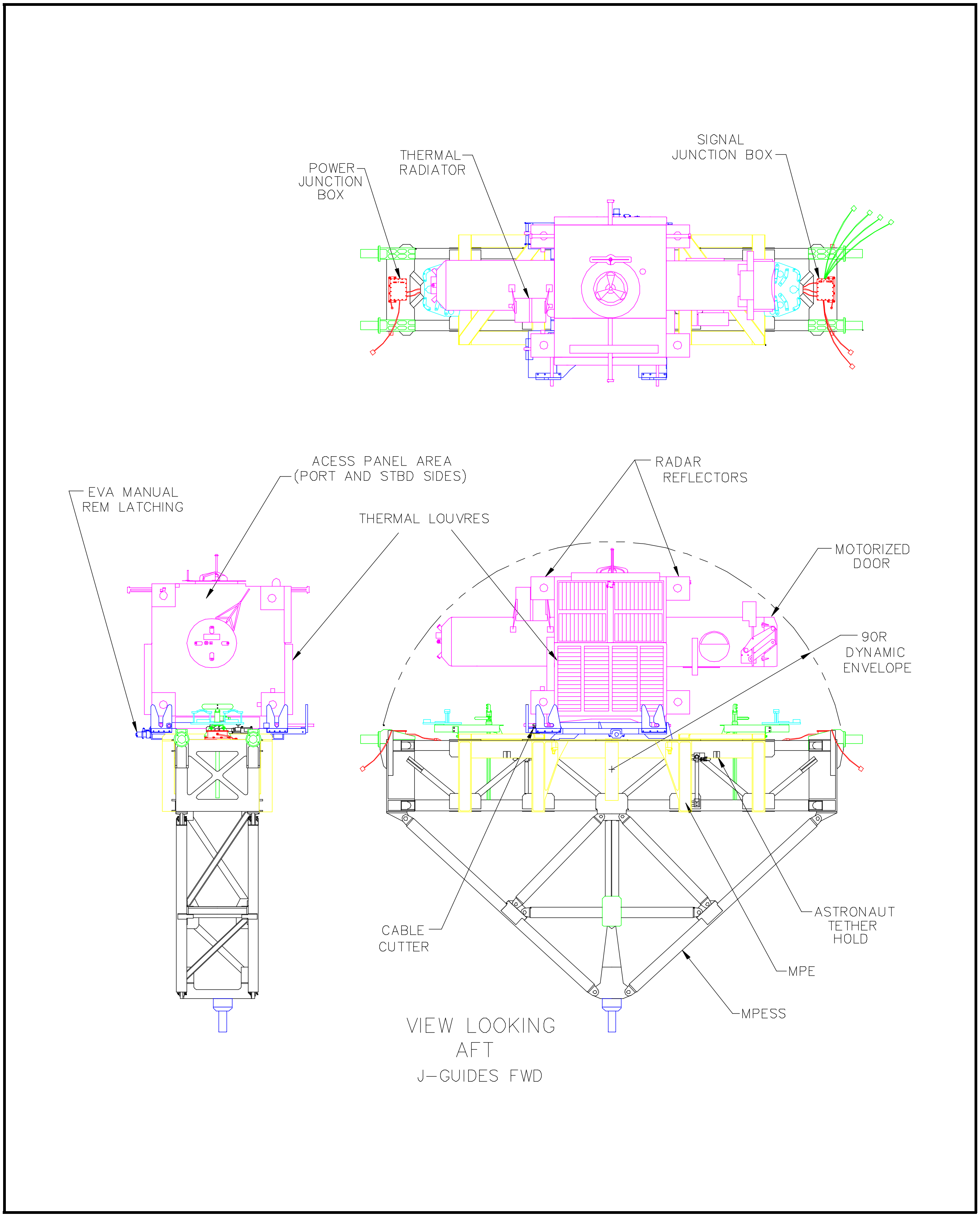

Figure 2 Spartan 201-03 Payload

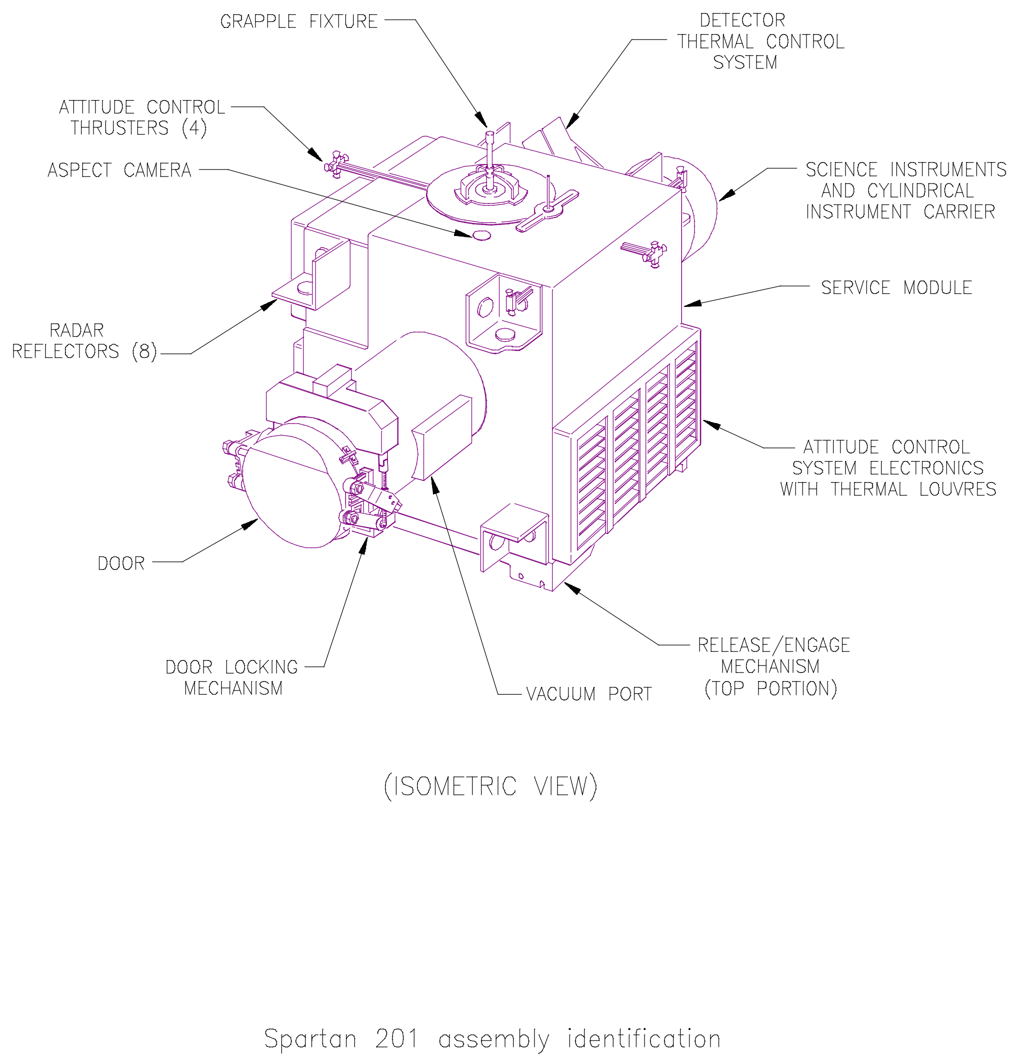

Figure 3 Spartan 201-03 Spacecraft

Goals of the SP201-03 Mission:

In 1991 the joint ESA-NASA Ulysses mission(7) to investigate the heliosphere at far from the ecliptic was launched toward Jupiter where the inclination of the orbit with respect to the ecliptic was altered so that the spacecraft would pass over the north and south polar regions of the sun. In 1993 the Ulysses spacecraft began to move southward in latitude and departed the region of the solar system modulated by the interplanetary current sheet. Although not intentionally planned, this coincided with the first flight of Spartan 201 on STS-56 in April of 1993. The second and this third flight of Spartan 201 were coordinated with the Ulysses south and north solar pole passages respectively. The scientific goal of the Spartan 201 flights was to investigate the morphology, dynamics, and physical conditions of the solar corona and heliospheric boundary region. The goal of the second and third missions was to coordinate the investigations with the Ulysses polar passages. Four azimuthal regions were selected for study by the scientific team supporting mission operations and these were communicated to the flight crew who entered these data into the SP201 spacecraft control program prior to deployment. The solar science targets selected for the SP201-03 mission are shown diagrammatically in figure 3.

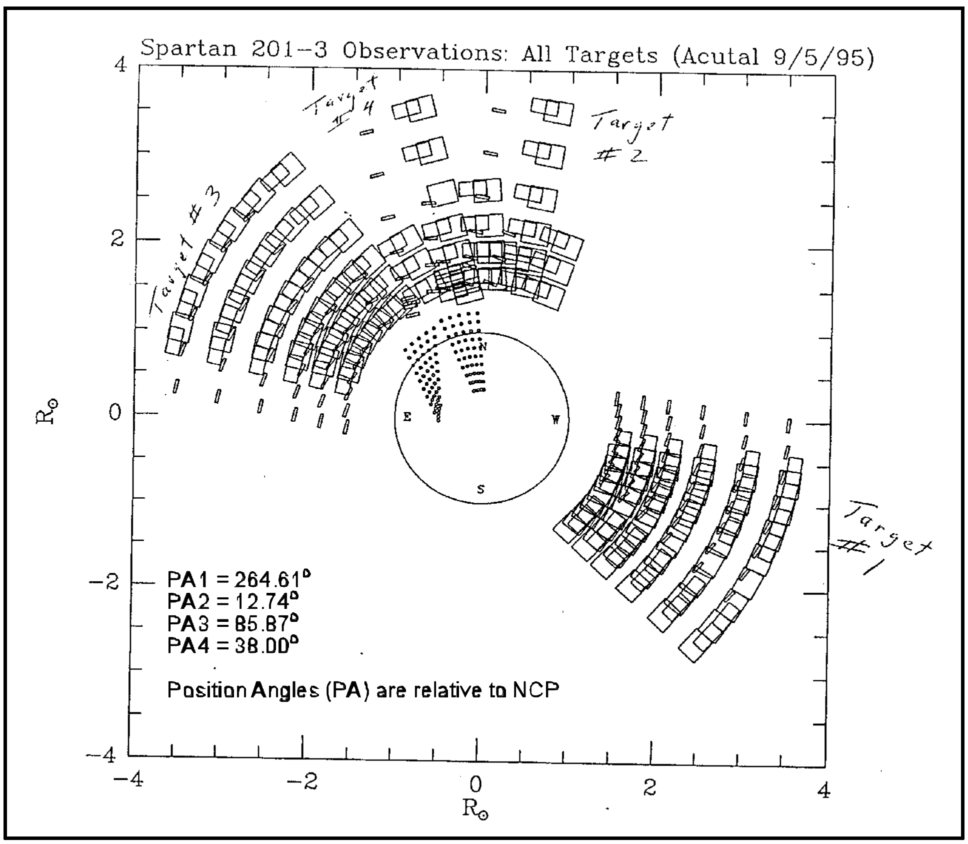

Figure 4 SP201-03 Solar Observation Targets

Ultraviolet Coronal Spectrometer Performance:

In the preliminary analysis of Spartan 201-03 data, SAO personnel determined that the UVCS/Spartan instrument performed as expected. An inspection of some of the observations from eight orbits suggests broad wings on the observed Hydrogen Ion (HI) Lyman alpha profiles in the north coronal hole as found in previous flights. HI Lyman alpha (Ly-alpha) profiles that were sampled from different coronal heights have count rates that are similar to those from the last Spartan 201 flight, indicating no large change in system efficiency for the instrument. Also, background levels in the sample data set indicate that the detector performance and instrument stray light levels were normal. A check of an observation of the narrow geocoronal Ly-alpha line demonstrated that the spectrometer was in focus.

There was one major hardware change for this mission. The Oxygen VI detector vacuum pump was replaced by a new one during the pre-flight characterization activities at SAO. The pump worked as planned during ground operations and during the mission. The planned shutdown of the pump power in science Orbit 6 and restart in Orbit 26 went exactly as planned. Experience from the Spartan 201-02 flight showed that the Oxygen VI detector could be operated safely without the pump after an appropriate initial pump down period to reduce outgassing. The pump is necessary to keep the detector evacuated when the instrument is on the ground.

The UVCS/Spartan observing program was modified for the third flight in order to optimize the coordinated science data to be obtained during the Ulysses north polar passage. The two coronal hole target patterns were placed in the north coronal hole to give a more complete coverage of the hole spanning from its center to the eastern edge. The streamer observation patterns were placed just to the east of the north polar coronal hole and in the southwest.

A second disk observation was added to the observing program in order to characterize, as a function of orbital position and look angle, the daytime atmospheric layers that are above Spartan's orbit. This observation was planned near the end of the mission to minimize the risk of losing science data should a malfunction occur. Unfortunately the recorded Spartan 201-3 mission ended prematurely when the tape recorder shut down prematurely approximately 2 hours before the end of science observations. This resulted in the loss of the observations from Orbits 26 and 27 which included the disk observations which would have been useful in interpreting the effects of the residual atmosphere on the Oxygen VI observations.

Detailed analyses of the data are in progress. The first preliminary results were given at the 1995 Fall American Geophysical Union (AGU) meeting. There was a full-day special session devoted to the Spartan 201 observations and theoretical results at the 1996 Spring AGU meeting.

A bibliography of UVCS scientific publications to date is presented in Appendix 1.

White Light Coronagraph Performance:

The Spartan 201 WLC was launched into low Earth orbit as part of the Spartan 201-03 payload on the STS-69 Space Shuttle Mission. The Spartan 201 spacecraft carrying the WLC was deployed on 8 Sept 1995 and successfully collected data concerning the distribution of material in the solar corona for a period of roughly 40 hours. The payload was then recovered and the data subsequently was dumped from the spacecraft recorder. At the present time the analysis and interpretation of the data collected on the third mission are progressing without significant difficulty. New results, including a new polar coronal hole electron density model, have been reported in a special session of the spring meeting of the AGU. It is expected that the analysis plan will be completed on schedule during the winter and spring of 1997. Figure 4 is a composite WLC solar corona image.

In the case of WLC, two of the target azimuths were located near the north polar region of the sun, and the remaining two pointings were aimed at the coronal hole-helmet streamer boundaries found on the east and west limbs. Since the field of view of the WLC includes an area which is at least 180 degrees of solar position angle to at least a height of 3.0 solar radii, the entire solar corona was imaged at some point during the data collection period. The instrument control program was programmed to run for 43 hours and during this time a data collection schedule was run which should have yielded about 1040 images. About one third of these were to be taken at spacecraft night (measures of thermal activity and electronic noise in the detector) and a net yield of about 800 useful images of the corona was expected. As a result of a spacecraft tape recorder anomaly, a net yield of 788 coronal images was collected during the 40 hour period of operation, leaving the investigation team with a data base about 1.5 -2 per cent smaller than pre-launch expectations. The usable images collected appear to be of uniform, high quality with the optical, mechanical, polarimetric, and photometric systems of the WLC operating at nominal performance levels. Three calibration sequences were conducted and two of these three subsets of the data have been used to apply a photometric calibration to the data. One software bug, not noticed during testing, was found in the flight control software of the system, and the effect of this error is to add a single 0.25 sec. and 1.503 sec. pair of clear images to the calibration sequence at the end of each calibration period. The short exposure is not suitable for scientific data analysis since the exposure time estimate is not accurate for such short exposures. The other image of the pair has been added to the analysis data base.

Post flight analysis of the data has shown that the pointing angles achieved are quite close to those requested, and that the image data is satisfactory for the anticipated investigation of the north polar hole and polar hole - helmet streamer interfaces. Coronal material is detected with satisfactory signal to noise over the range of altitude 1.4 to 6.0 solar radii in the helmet streamers and polar plumes are imaged to heights in excess of four solar radii from the solar limb. A modification to the WLC observing software for this mission resulted in a factor of three improvement in the signal-to-noise ratio for the polar coronal hole observations. The polarimeter system has allowed the combination of three polarized images into a single polarized brightness image (pB) which is superior in quality to those made during the previous Spartan flights. A characteristic of this mission's data set that is attributed to improved alignment between the coronagraph instrument optical axis and the two spacecraft sun sensors. Occulting system performance appears to have been of uniform, good quality though this mission. In three of the polarized brightness images (pB) there are streaks detected. Streaking has been noted in the imagery from all externally occulted orbital coronagraphs (ATM, SMM, Spartan, P-78-1,and SOHO) and this effect is normally attributed to the scattering of photospheric (solar) light by material in orbit with the coronagraph. In the case of the Spartan (pB) images, the streaks are found on only one of the three images used to make the composite of polarized brightness. This fact suggests that the typical angular velocity is of the order of 3 - 5 solar radii per 15 second exposure time (one solar radius is 16 arc minutes) which is a relatively slow proper motion in the plane of the sky and consistent with the hypothesis that the material is not too far from the coronagraph objective lens. In any case, the streaks are highly polarized and appear to vary in amplitude across the images, also consistent with the concept of small bits of material (frost, dirt, thermal blanket material, etc.) which are highly reflective and rotating slowly as they pass through the field of view. The net effect concerning data loss is trivial.

In summary, the data collected during the SP201-03 mission meet the observational requirements of the scientific questions of this mission. It is satisfactory to characterize the distribution of electron density in the solar corona and document changes to this distribution during the duration of the mission. The occulting system, the pointing system and the spacecraft pointing control systems functioned as expected and the resulting WLC data are of quality somewhat higher than those collected during the SP201-01 mission. In spite of some difficulties encountered with the recording system, the resulting data base used for analysis is about 98 % of what was anticipated and planned prior to the mission. The photometric quality of the most sophisticated data product, the composite polarized brightness images, is superior to those previously obtained. Analysis of the data is continuing and preliminary results were presented at the May 1996 meeting of the AGU.

Spartan 201-02 WLC Anomaly:

This extremely successful flight of the WLC follows the investigation and resolution[(8)] of a WLC anomaly that occurred on SP201-02. The SP201-02 WLC anomaly resulted in saturation of all WLC solar images and therefore no useful WLC data was obtained from the SP201-02 mission. It is notable that the improved alignment between the WLC optical axis and the spacecraft controlling sun sensors was a result of some of the work done in the aftermath of the SP201-02 anomaly.

A bibliography of WLC scientific publications to date is presented in Appendix 1.

Spartan Spacecraft Performance:

The performance of the carrier spacecraft subsystems is summarized in this section. The two flight anomalies in the Payload Functional Control System (PFCS) are described here. Selected flight engineering data and more detailed information is included in Appendices.

Attitude Control System (ACS) :

The ACS flight performance was flawless. The planned solar pointing during the orbital day pass and the inertial holds during orbital night were executed properly. WLC data confirmed correct

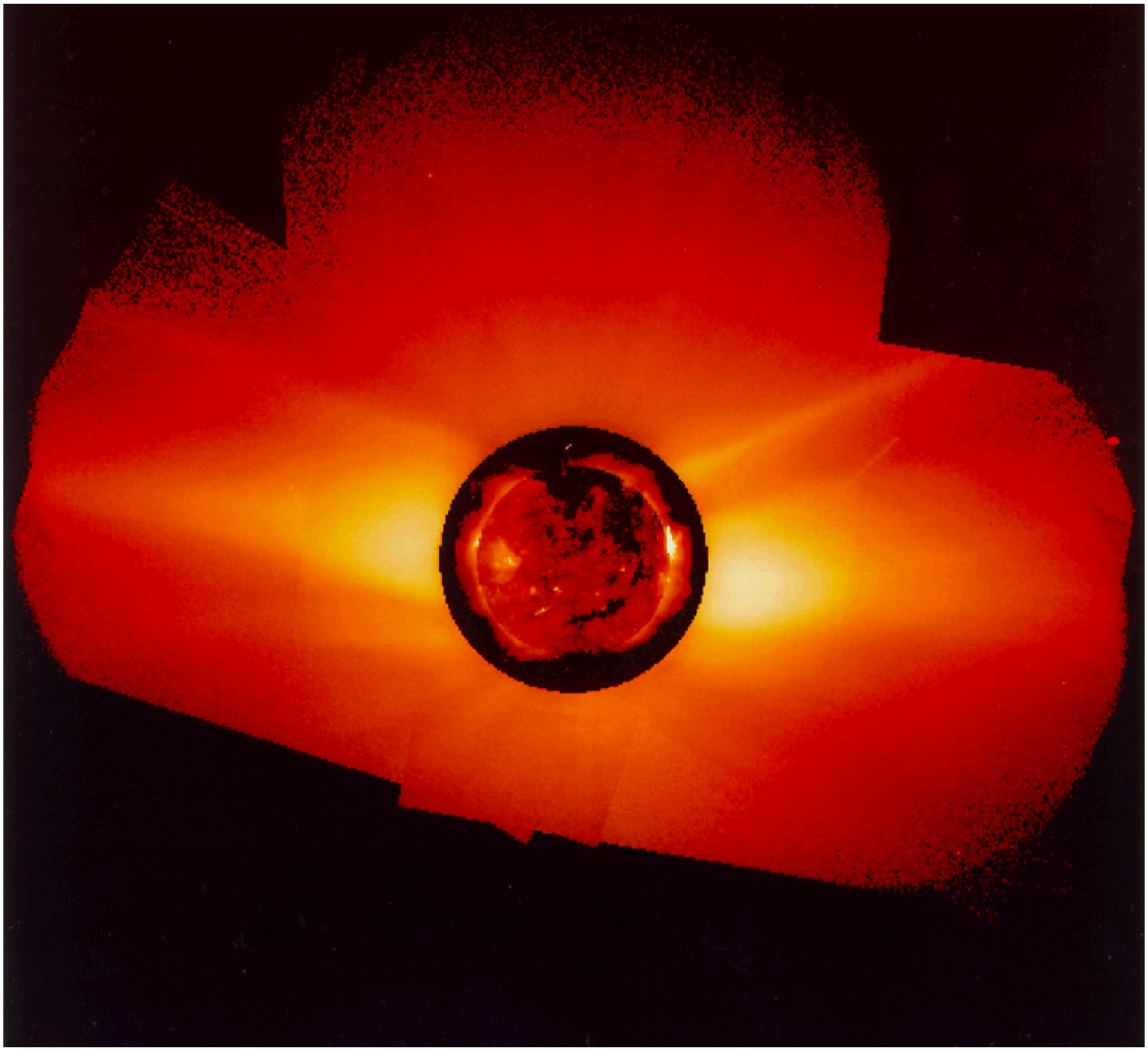

Figure 5 The Solar Corona from 1.3 to 6.0 $R_\odot$, 8-10 September 1995

An eleven image mosaic of the corona (in polarized brightness) is shown in this figure. The center of the image has been replaced with a day long integration of the Yohkoh SXT soft X-ray images of the solar disk, made thru the Al filter. Because the WLC Image comprises a sub field of view at any given roll angle, the entire corona is observed over the course of the mission, rather than at any given instant. The quantity pB (polarized brightness) is used for this image so that the so-called F-corona, light scattered of interplanetary dust, is removed from the image and the K-corona (electron scattered light from the solar corona) is presented with optimal contrast. Edges of the images seen in the mosaic are the result of real temporal variation in the solar corona, and the linear track seen at a distance of about 2.5 solar radii at the 2 o'clock position is thought to result from light scattered off of orbital debris located between the WLC and the sun.

instrument to sun sensor alignment and solar pointing. The Star Field Aspect Camera images confirmed correct 3rd axis pointing and also facilitated confirmation that the spacecraft continued to operate correctly from the time of premature tape recorder shutdown until End Of Mission (EOM).

Although activated due to an anomaly in the PFCS system the back-up Magnetic Attitude Control System (MACS) operated properly. Post flight analysis of the spacecraft attitude and body rates confirmed this.

Key ACS flight parameters are given below. Appendix 2 contains selected ACS flight data plots and a more detailed description of SP201-03 ACS flight performance[16].

Third Axis (Pitch Gyro) Drift Rate:	0.052 degree/Hr.	(0.10 degree/hr. max. allowable)
Estimated Deployment Attitude Error:	1.0 degree	(5 degree max.)
ACS GN_2 Pressure at EOM:	900 psi	(within predicted budget)
Body rate (MACS control) at Retrieval:	2 degree/min.	(Predicted average= 2 degree/min.)

Payload Functional Control System (PFCS):

The PFCS provides functional control, power, and data handling and storage for the SP201 spacecraft. The PFCS experienced two anomalies during the mission. Both of these occurred near the end of the mission timeline as indicated in the summary timeline presented earlier in the report. The anomalies are discussed in detail later in this section.

Command System: The PFCS properly controlled spacecraft function throughout the active science mission which terminated as planned at EOM. The Binary Interval Timing Electronics (BITE) issued all commands on schedule. Selected BITE commanding plots are shown in the telemetry plots in Appendix 3. The PGSC-BIA/SCD in-bay commanding interface performed without problems during Orbiter crew initialization and programming of the spacecraft. It is notable that during the flight the Orbiter Ku-Band Communications Adapter (KCA) system was used to downlink the PGSC log files for review on the ground.

Power System: The spacecraft power supply, which consists of the two LR350 Ag-Zn main batteries and the LR40 Ag-Zn MRS battery, performed as expected. 872 amp-hours (24 KWH_{28v}) were consumed leaving a 20 % margin without reserve for the flight. 39 amp-hours (1 KWH_{28v}) were consumed from the LR40 MRS battery, leaving an additional 26 amp-hrs. The power consumption includes the additional loss due to self discharge that resulted from the 50 day launch delay. The power consumption was well within the margins predicted by the SP201-03 power budget including the estimates for self-discharge loss. The buss voltages and currents throughout the mission are shown in the telemetry plots in Appendix 3. The power buss telemetry data is consistent with the mission timeline. Post flight inspection of the batteries showed no electrolyte leakage or battery box corrosion.

Data Handling: The Micro Pulse Code Modulation (MPCM) system properly collected, encoded and formatted the science and housekeeping data throughout the flight. Prior to the tape recorder failure at MET 1/15:46:21 data was properly recorded on the Tape Recorder. The Telemetry Data Processor

(TDP) system was successfully used post flight to read and format the data and produce the science and engineering data products[9] that have been released to the science and engineering teams.

Tape Recorder Anomaly:

The SP201 Tape Recorder anomalously reversed tape direction early before the actual End Of Tape (EOT). The Tape Recorder is configured to complete three passes during the SP201 mission (forward-reverse-forward) with data being recorded on 4 of the 12 tracks each pass. The first pass ended at MET 00:12:33 instead of the 00:14:50 anticipated. The second pass was shortened as a result of the early first pass reversal and the third pass anomalously stopped prematurely in a manner similar to the first pass.. The net effect of the false triggering of EOT was a tape recorder shutdown 3 hours and 44 minutes early. This resulted in the loss of data from the last two science observation orbits.

The initial investigation revealed evidence of tape stacking problems and subsequent mechanical contact and dragging between the outer tape reel and the housing. It is believed this dragging caused variations in tape speed that triggered the false EOT. Telemetry shows variations in tape speed shortly before the premature EOT. The SP201 Tape Recorder experienced tape stacking problems during preflight testing that were not fully diagnosed because of time constraints[10]. Investigation of the tape stacking problems and this specific anomaly is still in progress.

Minimum Reserve Shutdown (MRS) Anomaly:

The SP201-03 spacecraft was found to be in MRS mode when the Orbiter returned to it for retrieval. This necessitated an Orbiter fly-around to achieve proper orientation for RMS grappling. Subsequent postflight investigation revealed that none of the off-nominal conditions (low consumables or high rotation rates) that should trigger MRS had occurred. MRS was initiated in spite of a healthy spacecraft and therefore MRS initiation was an anomaly.

The cause of the initiation of MRS during the SP201-03 mission has been identified as a latent design implementation error in the MRS system compounded by a recent change to the system. As currently configured the spacecraft will automatically go into MRS 90 seconds after EOM at SP201 MET 43:30. The intended EOM configuration was ACS wide limit duty cycle control in retrieval attitude. Both the unexpected initiation of MRS and the post flight spacecraft configuration have been duplicated during post flight testing at GSFC[11]. Spartan 201 was retrieved at MET 47:20. The cause of the anomaly is explained in more detail below:

The MRS system has two main components: 1) the MRS control electronics and 2) the Magnetic Attitude Control System (MACS). The MRS electronics monitor the spacecraft systems and configure the spacecraft in a safe hold mode should any of the following conditions arise: Low main battery voltage, low ACS GN_2, or high rotation rates. MRS mode shuts down most spacecraft systems and switches the MACS into control mode. Prior to SP201-03 the MRS control electronics was powered by the main LR350 battery bus thru the PFCS. This is also the location of the MRS system's low voltage monitor point for the main battery voltage. The MACS is powered by the LR40 recovery bus. The SP201 flight program powers down the PFCS at EOM. The MRS system powers down the PFCS in the event MRS is initiated. The result of the previous (SP201-01 & SP201-02) configuration was that the MRS control electronics would be powered off during the initiation of MRS. Although the system performed properly during testing this was determined to be undesirable. A modification was implemented prior to the flight of SP201-03 that moved the source of MRS control electronics power from the PFCS to the LR40 recovery bus. The LR40 recovery bus remains on during MRS. Unfortunately the implications of having the MRS voltage monitor point located in the PFCS, (which is powered down at EOM) were not realized at the time of the modification. When EOM occurred during the SP201-03 mission the MRS system interpreted the power down of the PFCS as a low voltage condition and after the programmed 90 second wait period initiated MRS. On previous SP201 flights the MRS control electronics was also powered down at EOM and thus MRS was not initiated. After reviewing the design of the MRS system it is clear that the proper implementation of the MRS system for SP201 should have had the MRS control electronics powered by the LR40 recovery bus and the MRS LR350 main bus voltage monitor located at a point that remains on after EOM. Furthermore, a review of the SP201 test procedures revealed that this flaw is masked by the spacecraft/GSE configuration during ground testing. The MACS has always been correctly connected to the LR40 recovery bus. Appropriate modifications will be implemented and tested prior to SP201-04.

Thermal Control System:

The thermal control system performed nominally. All flight temperatures were maintained within the required limits and correlated well with the analytical predictions [12]. Selected temperature plots are presented in Appendix 4. Thermal performance data is summarized below:

Service Module Internal Temperature (min./max. ^{0}C):	+10/+22	(0 to +40 allowable)
Instrument Carrier Temperature (min./max. ^{0}C):	+13/+24	(+10 to +30 allowable)

Mechanical Systems:

All mechanical subsystems performed nominally. The structure sustained flight loading without damage or permanent deformation. The Double Arc Door (DAD) and the Bay Vent Door (BVD) motor driven doors operated correctly. Door duty cycle times and power consumption were as expected.

The Instrument Carrier (IC) maintained vacuum integrity pre- and post-flight. IC pressure levels and the measured leak rate are given below:

Preflight IC Pressure (L-40 days):	150 millitorr
Post-flight IC Pressure (L+19 days)	50 millitorr
Preflight final leak-rate	1.22E-5 Torr-liter/sec

The REM latch system performed nominally with no difficulties experienced in unberthing or berthing the spacecraft. The SP201 REM (S/N 01) Ready-For-Latch indicators had been modified and readjusted in accordance with the specifications developed prior to the SP204 mission on STS-63. Orbiter telemetry verified nominal REM duty cycle time and power consumption. The JSC supplied Mirror/Berthing Camera system performed well, verifying proper alignment had been achieved and maintained between the camera and mirror.

Overall Payload Condition:

The SP201-03 payload showed no evidence of damage or deterioration. There was negligible degradation of the exposed surfaces due to orbital atomic oxygen.

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2) NASA JSC, “Cargo Systems Manual: Spartan 201/Release-Engage Mechanism (REM)” JSC-26955, May 1995

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7) NASA JPL, “Ulysses Mission Status Report No. 5, JPL D-7959-5, 7/94

8) Tooley C., Memorandum to B. Bangs/GSFC 301.0, “Review of Spartan White Light Coronagraph”, SP201-EN-9, 2/13/95

9) Spartan 201-03/STS-69 Engineering Data Books, GSFC 740 CM # SPTN-SPEC-007

10) Tooley C., “SP201-03 Preship Review Presentation Package”, GSFC 740 CM # SPTN-REVW-003, 4/20/95

11) Kinder R., Memorandum to C. Tooley/GSFC 741.2, “MRS Circuit Demonstration”, 12/1/95

12) Tolson W., Memorandum to C. Tooley/GSFC 741.2, “STS-69 Thermal Subsystem Flight Data versus Analysis”, 3/15/95

13) Pownell J.E., SP201-01 Mission Report, 10/10/93, GSFC 740 CM # SPTN-OPS-007

14) Tooley C., SP201-02 Engr. and STS-64 Flight Data, 5/95, GSFC 740 CM # SPTN-SPEC-008

15) NASA HQ, “SOHO: Between Earth and Sun, *Space Physics Topics*”

16) Kiefer R., Memorandum to C. Tooley/GSFC 741.2, “ Flight Performance Of ACS on Spartan 201-03", CTA Memorandum # RDK/95/017, 11/30/95

Acronym List

MET	Mission Elapsed Time
SAO	Smithsonian Astrophysical Observatory
UVCS	Ultraviolet Coronal Spectrometer
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
WLC	White Light Coronograph
SOHO	Solar and Heliospheric Observatory
AGU	American Geophysical Union
HI	Hydrogen Ion
ATM	Apollo Telescope Mount
SMM	Solar Maximum Mission
PFCS	Functional Control System
ACS	Attitude Control System
MACS	Magnetic Attitude Control System
EOM	End Of Mission
EOT	End Of Tape
BITE	Binary Interval Timing Electronics
PGSC	Payload General purpose Support Computer
BIA	Bus Interface Adapter
SCD	Spartan Control Decoder
KCA	Ku-Band Communication Adapter
MPCM	Micro Pulse Code Modulation
TDP	Telemetry Data Processor
DAD	Double Arc Door
BVD	Bay Vent Door
REM	Release-Engage Mechanism
IC	Instrument Carrier
GSE	Ground Support Equipment
STS	Space Transportation System

APPENDIX 1

Bibliography of Spartan 201 Science Publications

3 pages

UVCS Recent Publications:

(SP201-01)

Kohl, J. L., Strachan, L., and Gardner, L. D. 1996, ``Measurement of Hydrogen Velocity Distributions in the Extended Solar Corona" (submitted to the Astrophys. Journal Let.).

Kohl, J.L, Gardner, L.D., Strachan, L., and Hassler, D.M., 1994, ``Ultraviolet Spectroscopy of the Extended Solar Corona During the Spartan 201 Mission", Space Sci. Rev., 70, 253

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Strachan, L., Gardner, L.D., Hassler, D.M., and Kohl, J.L. 1994, ``Preliminary Results from Spartan 201: Coronal Streamer Observations", Space Sci. Rev., 70, 263

Strachan, L., Gardner, L. D., and Kohl, J. L. 1996, ``Spatial distribution of Proton Temperatures and Outflow Velocities in a Coronal Streamer" (to be submitted to the Astrophys. Journal Let.)

(SP201-02)

Cohen, C.M.S., Galvin, A.B., Gloeckler, G., Ko, Y-K., Strachan, L., Gardner, L.D., Kohl, J.L., Guhathakurta, M., Fisher, R.R., Geiss, J. and von Steiger, R. 1995, ``Initial Results of a Collaboration between SWICS/Ulysses and Spartan 201 Observations of the Southern Polar Coronal Hole," EOS, Trans. AGU, Suppl. 76, 241.

Kohl, J., Gardner, L. D., Strachan, L., Cohen, C. M. S., Galvin, A. B., Gloeckler, G., Guhathakurta, M., Fisher, R. R., Ko, Y-K., Geiss, J, and von Steiger, R. 1996, ``Proton Temperatures, Electron Temperatures, and Outflows in the Extended Solar Corona" (to appear in Publ. Astron. Soc. Pacific)

(SP201-03)

Strachan, L., Gardner, L. D., and Kohl, J. L. 1995, ``New Results for Outflow and LOS Velocities in the Solar Wind Acceleration Region of the Corona," BAAS, 27(2), 970.

WLC Recent Publications:

(SP201-01)

Temperature of polar coronal rays and high latitude streamers, Guhathakurta, M., Fisher, R. and Strong, K., submitted to Astrophysical Journal Letters, 1996.

An empirical study of the temperature profile in the south polar coronal hole, Yuan-koen Ko, Fisk, L., Geiss, J., Gloeckler, G. and Guhathakurta, M., submitted to Journal of Geophysical Research, 1996.

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APPENDIX 2

Spartan 201-03 ACS Performance Data

5 pages

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Reply to Attn of:

Memorandum RDK/95/017

November 30, 1995

TO: Craig Tooley 741.2 / Spartan 201-3 Mission Manager

FROM: Ronald Kiefer 745[redacted] CTA

COPY: Fred Witten - ACS/745.1; Leonard Strachan Jr. - Harvard-Smithsonian Center for Astrophysics; Greg Card - High Altitude Observatory, Instrumentation Group; Tom Collinson - ACS/745.1; Dr. Dick Fisher - Astrophysics/562.6

SUBJECT: **Flight performance of ACS on Spartan 201-3**

The ACS performed precisely as planned. Both LISS controlled on the sun at their appointed times showing virtually no offset between each other. The gyros controlled perfectly during each nightpass. The full time use of the Pitch gyro controlled the third axis with minimum drift rate. The star-field photos from the aspect camera confirmed correct science-pointing throughout all phases of the mission. The gas consumption was identical to the quantity used on the previous flight of Spartan 201-2. The Magnetic Control System performed successfully for the last 4 hours of the 47 hour mission. Therefore, the ACS exercised every one of its many operational functions, all on-time, with each one accurately accomplishing the desired control and maneuvers.

The 65 aspect camera photos clearly showed: (1) that even though the tape recorder stopped prematurely, the two remaining solar-observation orbits did take place as planned — they simply were not recorded, (2) that the third axis pointed at all the correct positions around the sun's disk, and (3) that the pitch gyro (3rd axis control) drift rate was 0.052°/hour — well within the system specification of $\leq$ 0.10°/hour.

After one hour into the mission, the pointing position of the third axis was 1.0° degree from that of the science-requested, pointing angle. This position error of 1.0° is to the left as you look at the sun, i.e., counter clockwise with respect to the center of the sun. The 1.0° pointing error probably existed at Spartan release from the positioning angle set by the Orbiter's RMS. Several hours later during solar observations of orbit 27, the position error had increased to 3¼ degrees. The 2¼° shift was caused by the drift rate of the pitch gyro.

After the Orbiter landed at KSC, the pneumatics' tank pressure measured 900 PSIG. Before flight, the tanks were filled with 3000 PSIG of Nitrogen. The Nitrogen usage during Spartan 201-3 was identical to that consumed on the previous Spartan 201-2 flight.

National Aeronautics and
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Goddard Space Flight Center
Greenbelt, MD 20771

Reply to Attn of: Memorandum RDK/95/017 **(continued)** November 30, 1995

The MCS started to control the attitude 90 seconds after Instrumentation EOM at 43:30:00 MET. The MCS continued control for 3¾ hours until the Orbiter snagged Spartan 201-3 with the RMS. The Spartan spacecraft, at the time, was rotating at twice the orbital rate — just as advertised. The rate of motion was easy to measure because the Orbiter had to move at that same rate to allow a smooth *grappling*. This 3¾ hour period was an excellent opportunity for the MCS to demonstrate how well it could control the spacecraft's attitude; because the science portion of the mission had finished and Spartan was simply *waiting for Retrieval by the Orbiter*.

The attached copies of a chart recording (two pages) display information extracted from the flight tape recorder. They illustrate ACS telemetry signals for (1) an orbit sunrise, and (2) a sunset. The chart recorder data was compressed to show you a larger snapshot segment of the mission. The spacing between each of the narrow, vertical chart lines represents 8 seconds.

In general, the following scenario occurs: The Spartan attitude is controlled by the gyros. The two LISS watch the sun rise from behind the earth's horizon as the Spartan goes from nightpass to daypass. Once the sun has risen enough for both LISS to acknowledge that the bright object is indeed the sun, the bilevel *Common LISS Sun Presence* telemetry goes from 0V to 5V — see top portion of the chart. One and a half minutes after the sun is detected, a 118° PCCW maneuver is performed — Remote Adjust #1. The maneuver takes 118 seconds from start to finish. Thirteen minutes after sunrise, LISS 1 is given control of the spacecraft attitude so it can keep the Sun at the center of its field-of-view.

Note the two *high gain* telemetries as the sunrise occurs. Both signals are a straight line until the sun creeps into the field-of-view. As the sun intensity increases, the signals vary until they finally settle down to a steady line to indicate the error measurement. Both *high gain* scales are 5.8 arc minutes full-scale with zero error at midscale. You can see that neither signal is exactly midscale. The off-center signal indicates (1) how much the Sun moved since the last time the LISS controlled on the Sun (which was ≈55 minutes earlier, just before going into nightpass), and (2) how much the gyro drift affected the Sun-alignment during that time.

The three saw-toothed composite error signals show the movement of each axis as it moves back and forth across their axis' center point — a gas-valve-trip deadband of ±10 arc seconds.

The Sunset occurred about 3 minutes after the attitude control transferred from LISS 1 control back to gyro control. Once again, you can see the sun error deflection on the *High Gain* signals as the sun intensity decreases from setting behind the horizon; and the signal flat-lining after the sun is gone.

These chart strips have been included in this report to illustrate information available from the flight tape recorder. Approximately 120 different ACS telemetries were recorded during the flight. These telemetries permit recreation of flight performance with a fair amount of detail.

In summary, the ACS performed perfectly throughout the entire Spartan 201-3 mission.

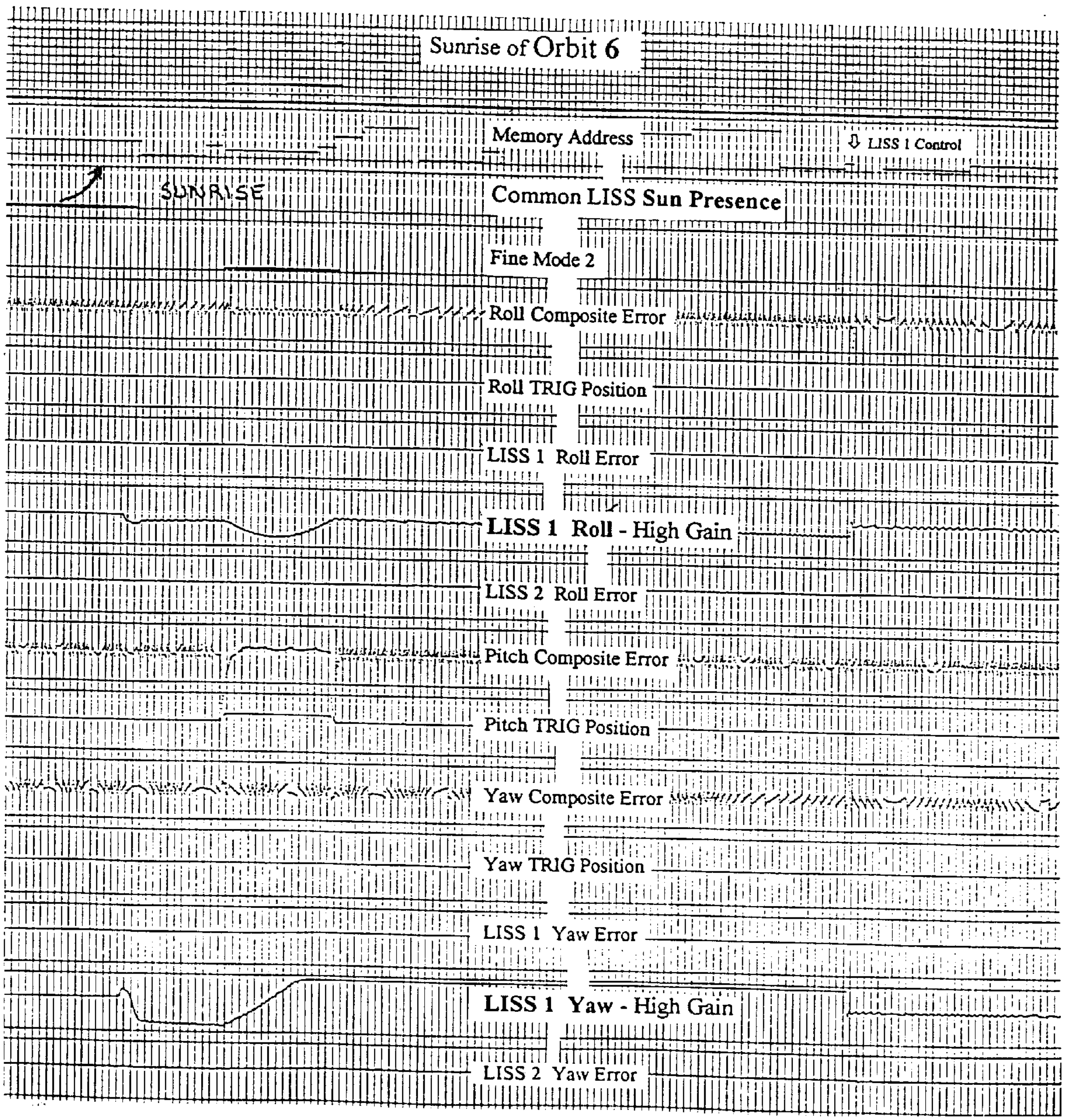
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

Reply to Attn of

Memorandum RDK/95/017 **ATTACHMENT** 1 of 2

November 30, 1995



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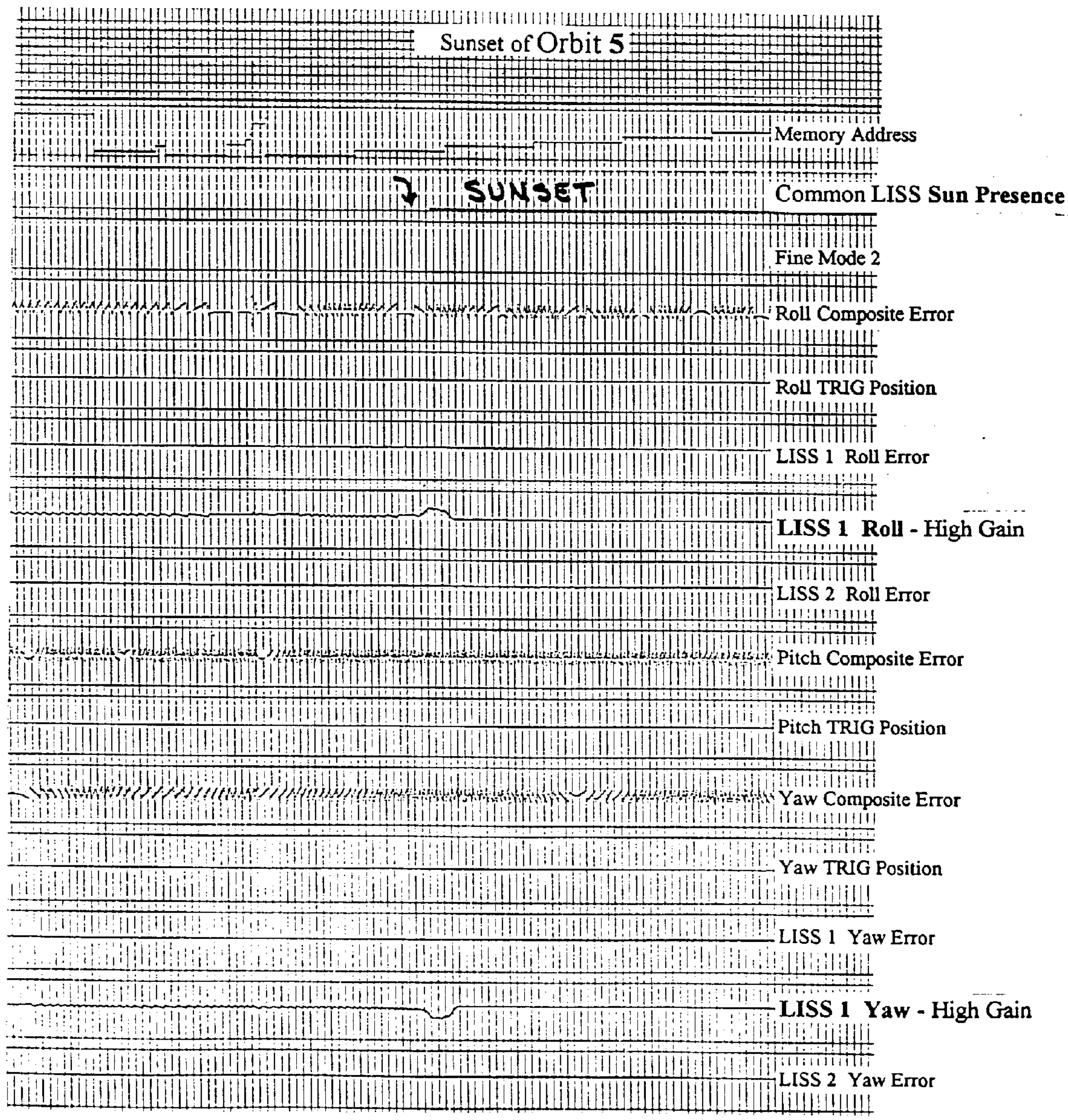
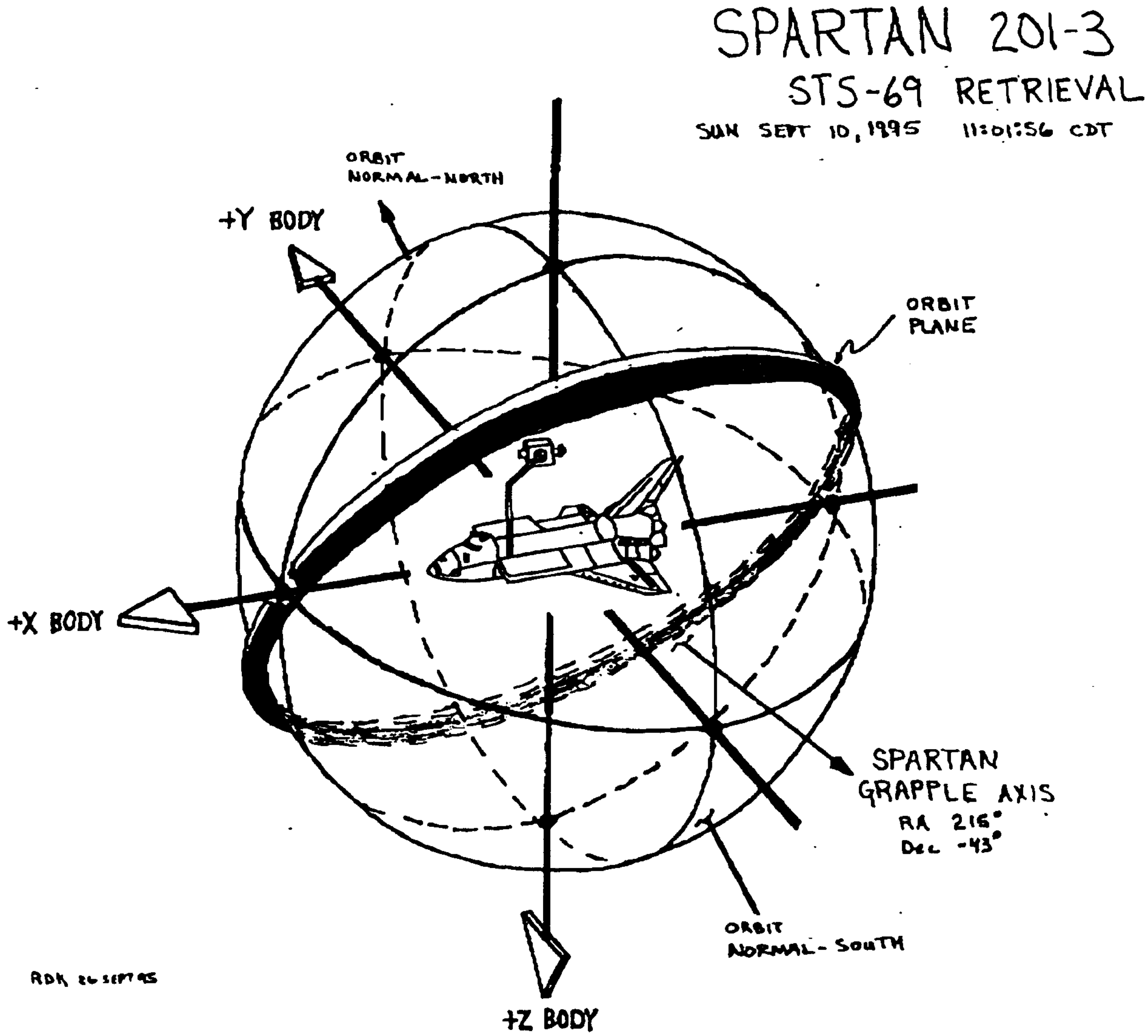
Greenbelt, MD 20771

Reply to Attn of

Memorandum RDK/95/017 **ATTACHMENT 2 of 2**

November 30, 1995




SPARTAN 201-3
STS-69 RETRIEVAL
SUN SEPT 10, 1995 11:01:56 CDT
ORBIT NORMAL-NORTH
+Y BODY
ORBIT PLANE
+X BODY
SPARTAN GRAPPLE AXIS
RA 216°
DEC -43°
ORBIT NORMAL-SOUTH
+Z BODY

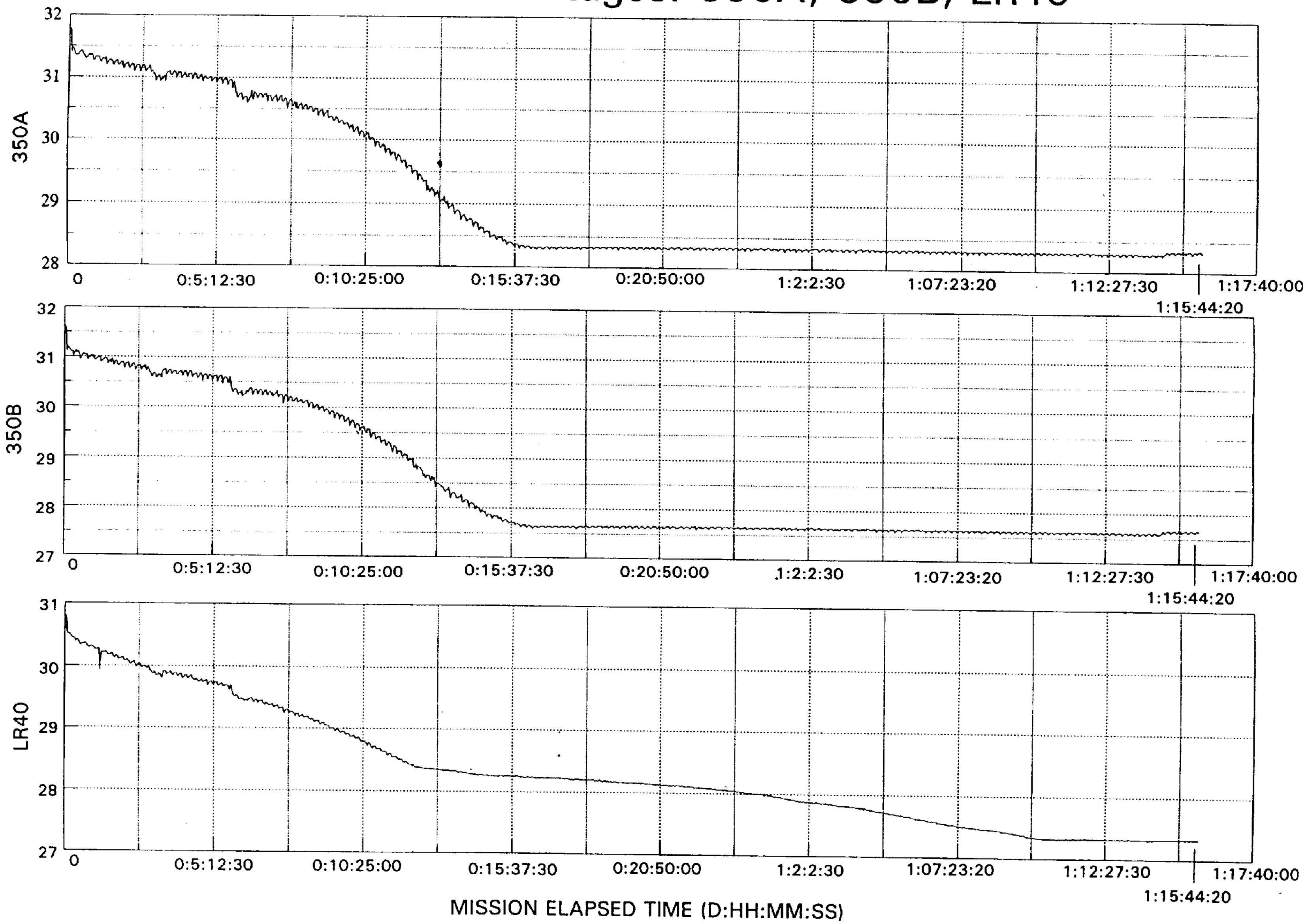
APPENDIX 3

Spartan 201-03 PFCS Performance Data

6 pages

Flight Data,
SP201-3 11-2-1995

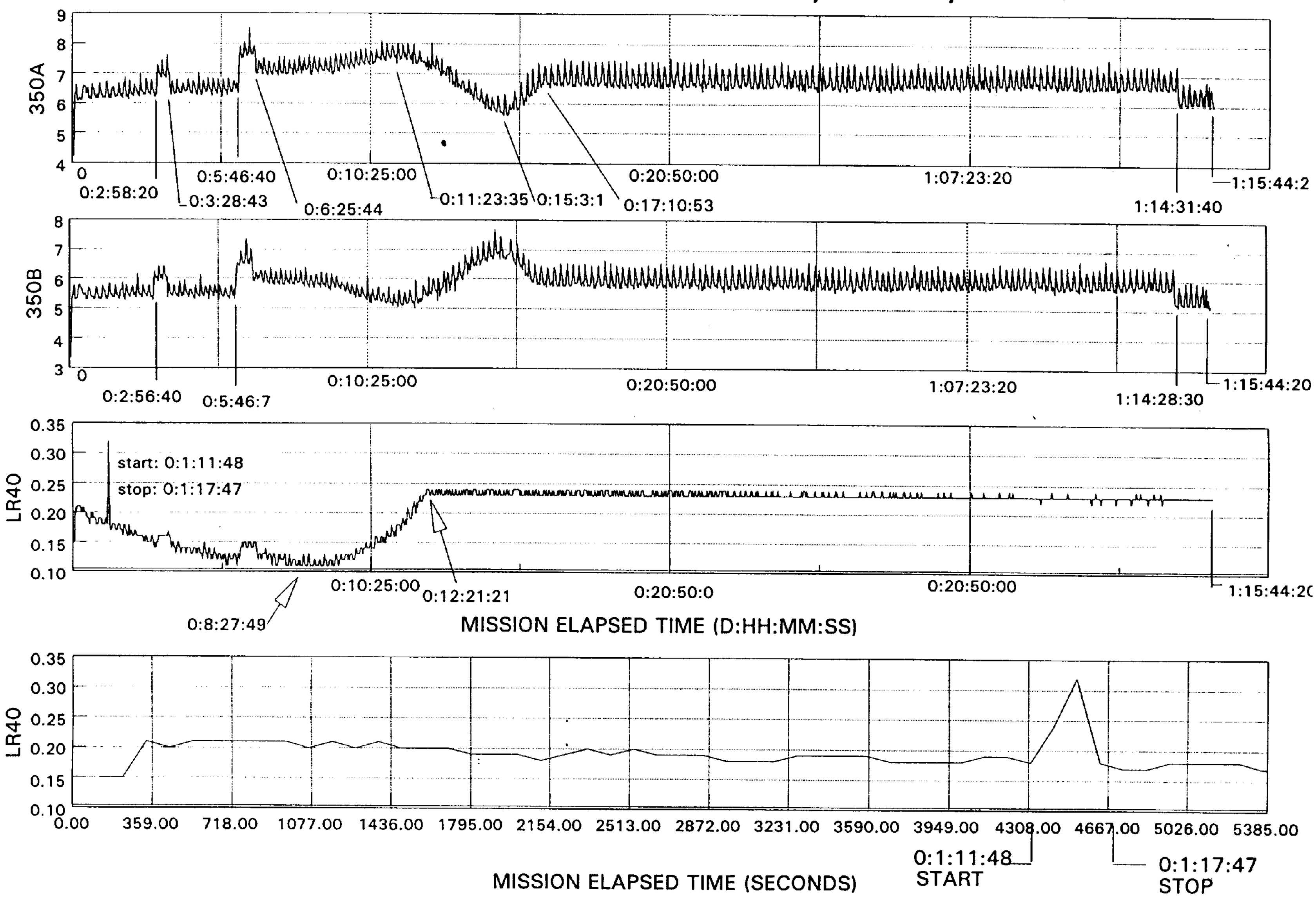
Main Power Voltages: 350A, 350B, LR40



SP2013RP.WPD Appendix 3

Flight Data
SP201-03 11-2-1995

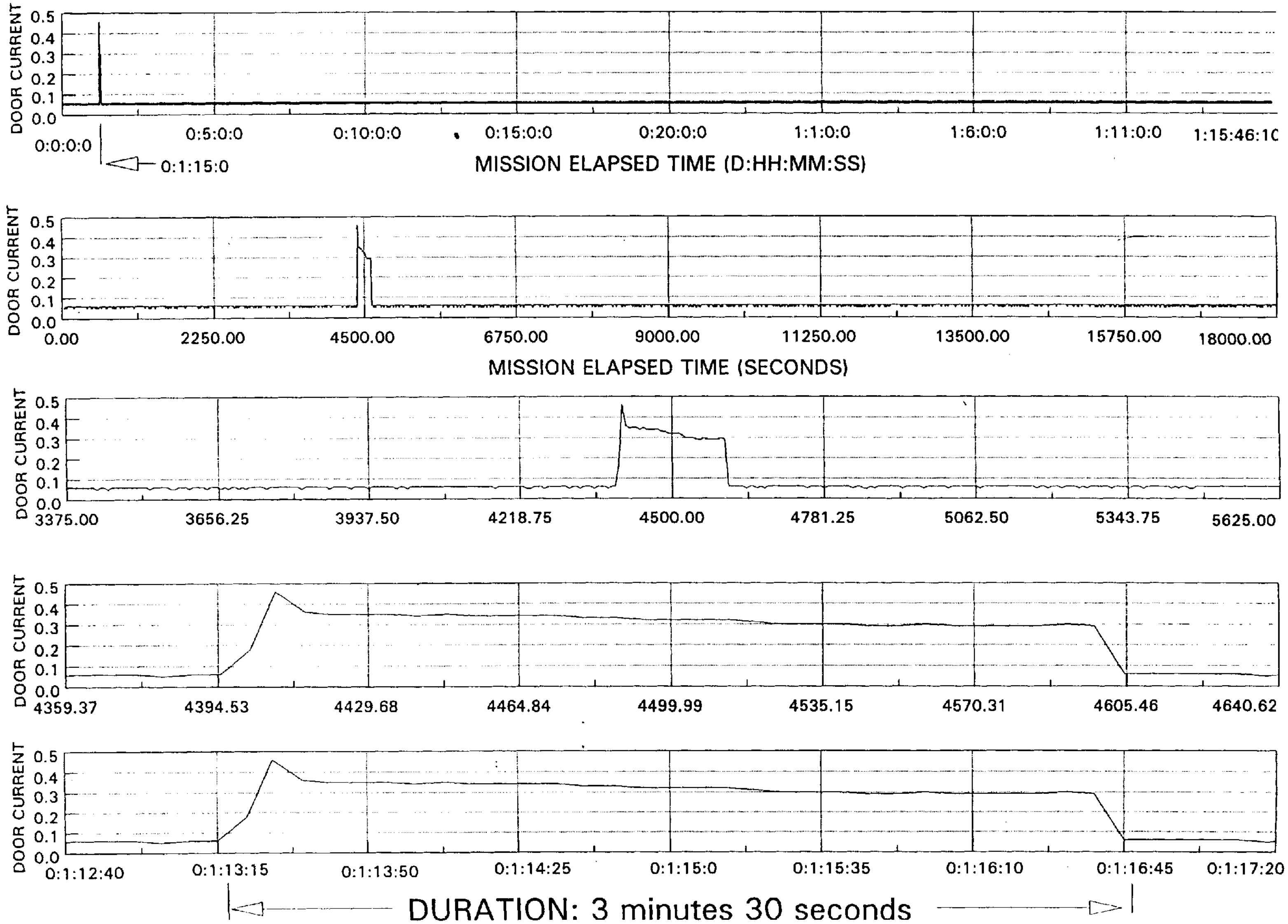
Main Power Currents: 350A, 350B, LR40



SP2013RP.WPD Appendix 3

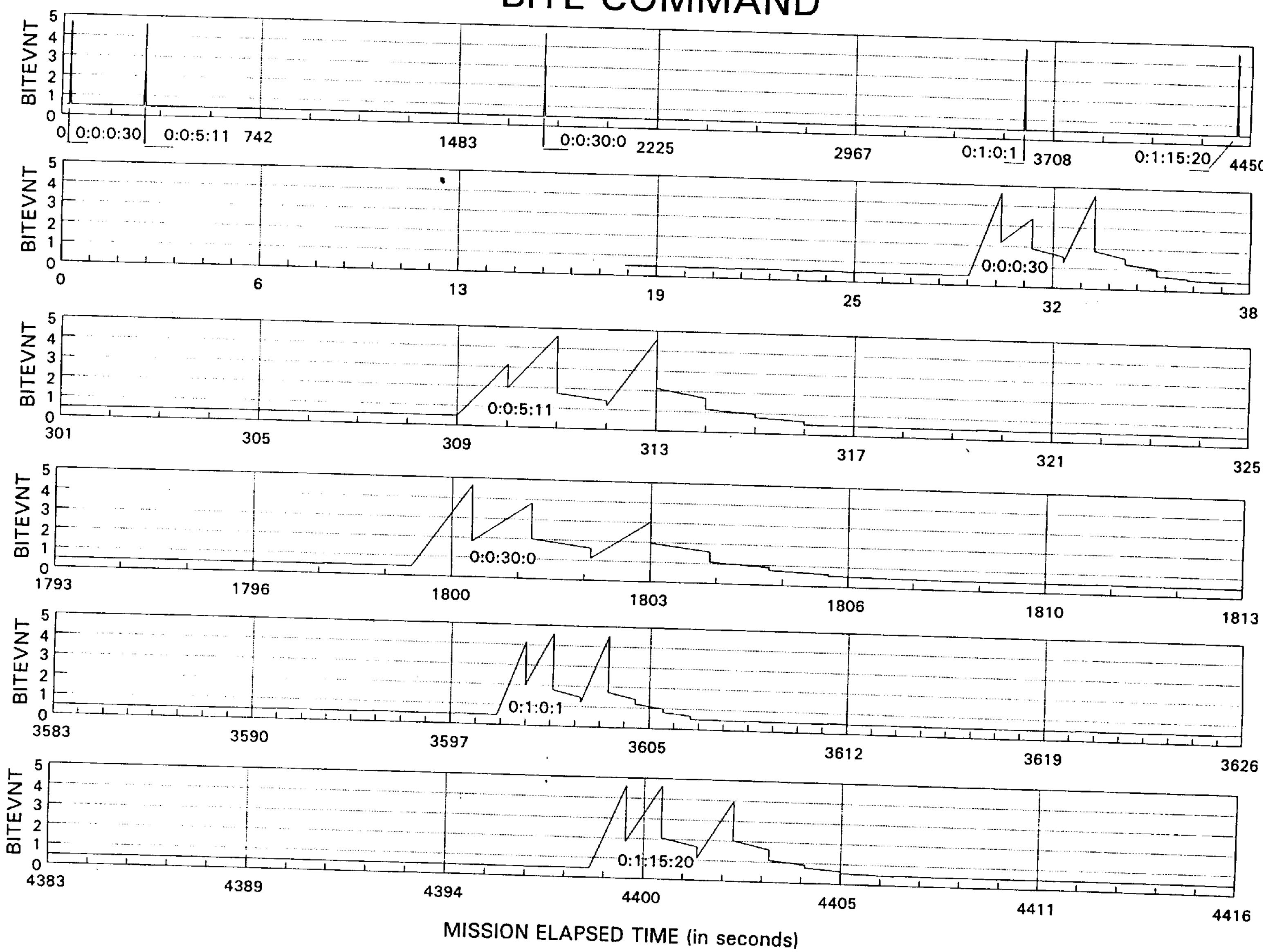
Flight Data
SPARTAN 201-03 11-2-1995

DOOR CURRENT



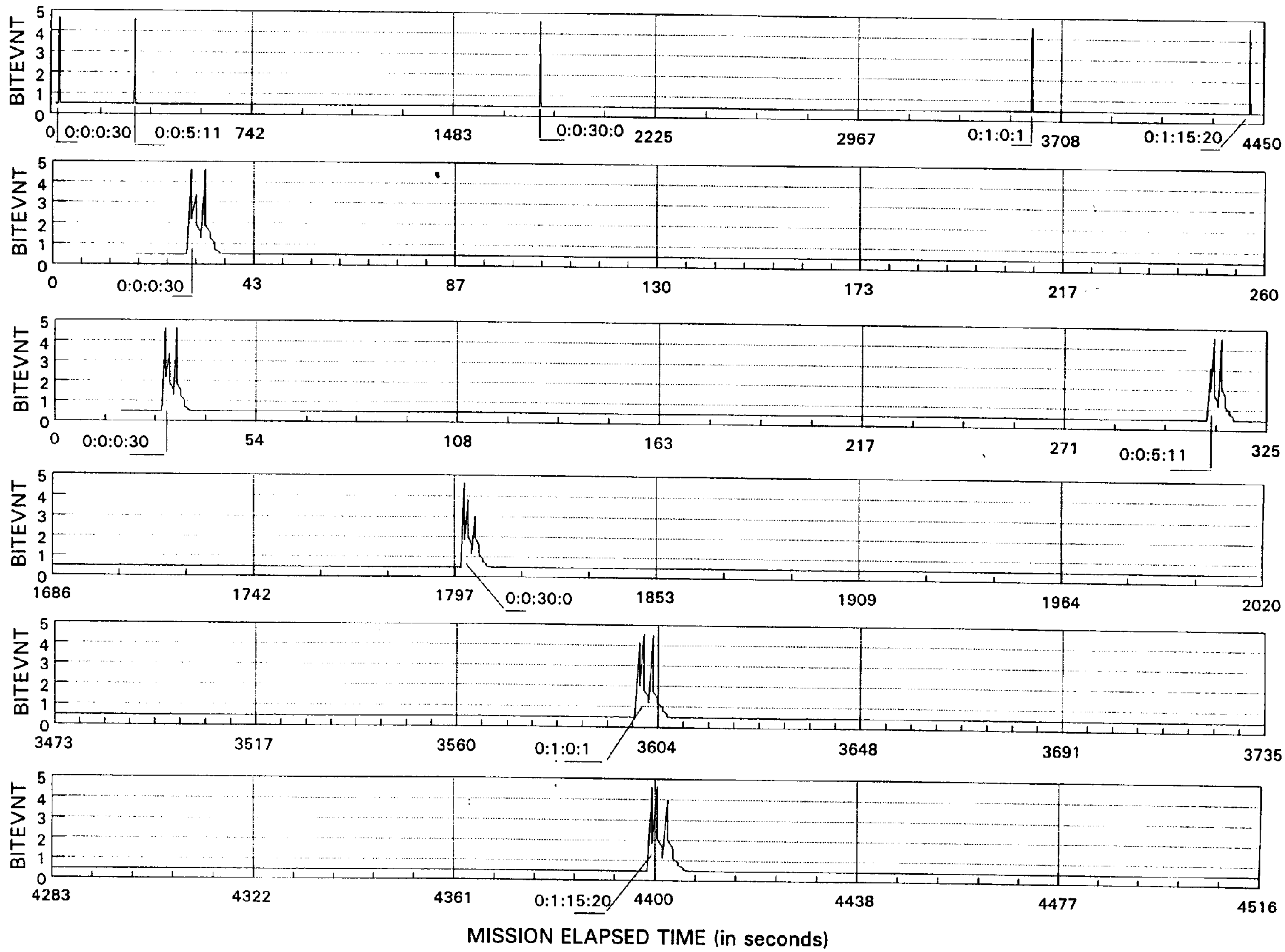
Flight Data
SP201-03 11-2-1995

BITE COMMAND



Flight Data
SP201-03 11-2-1995

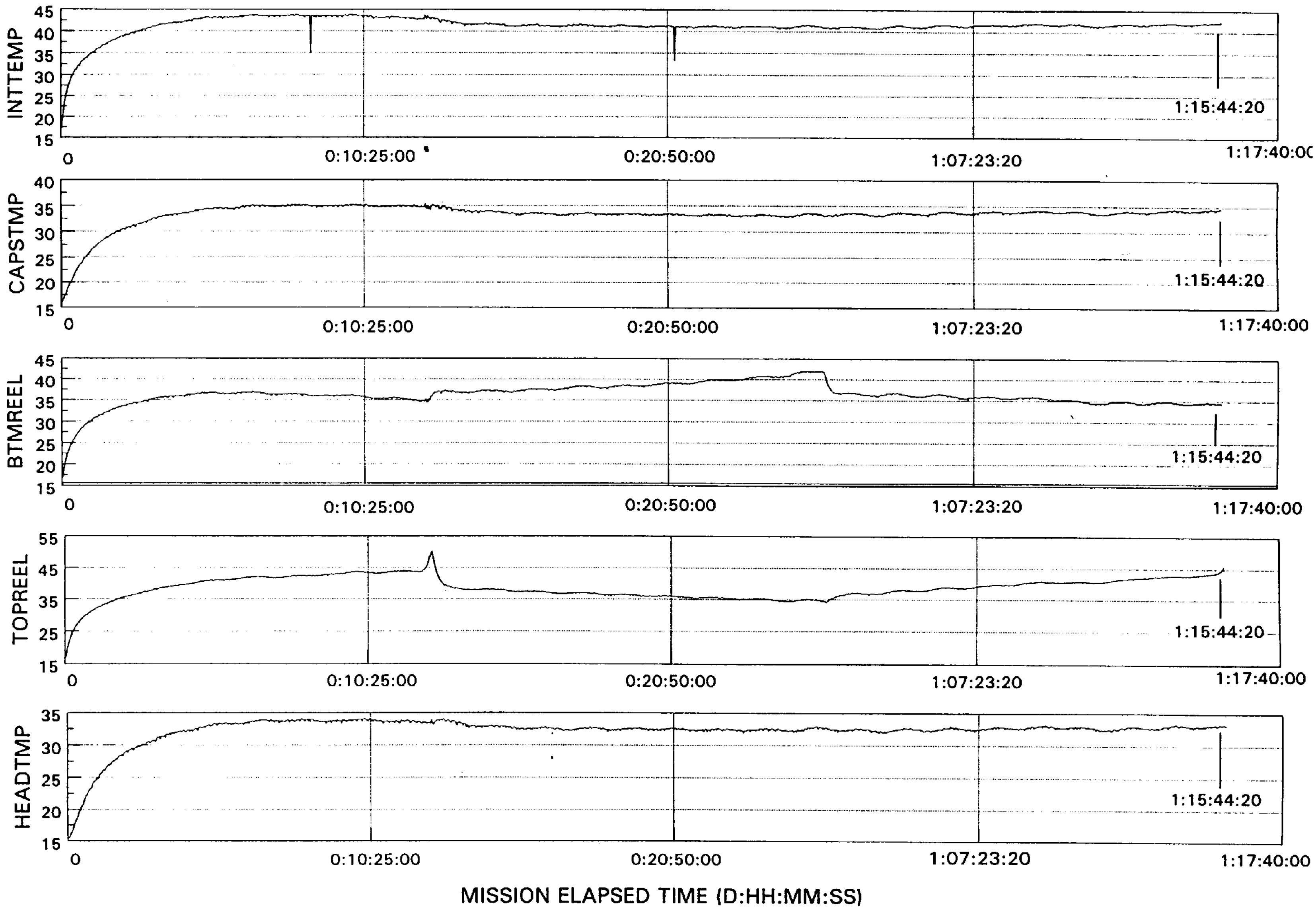
BITE COMMAND



SP2013RP.WPD Appendix 3

Flight Data
SP201-03 11-2-1995

Mars Tape Recorder Temperature



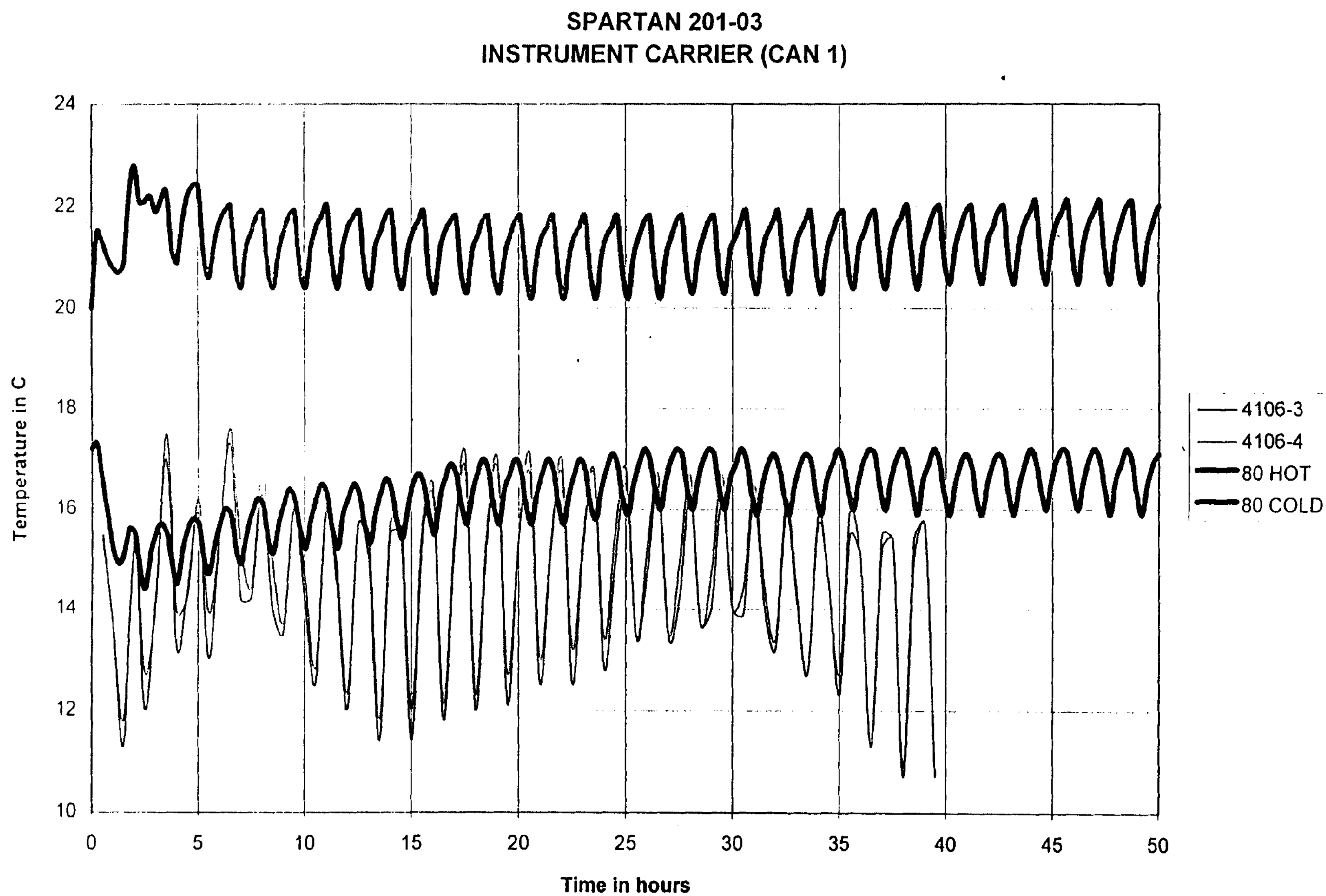
SP2013RP.WPD Appendix 3

APPENDIX 4

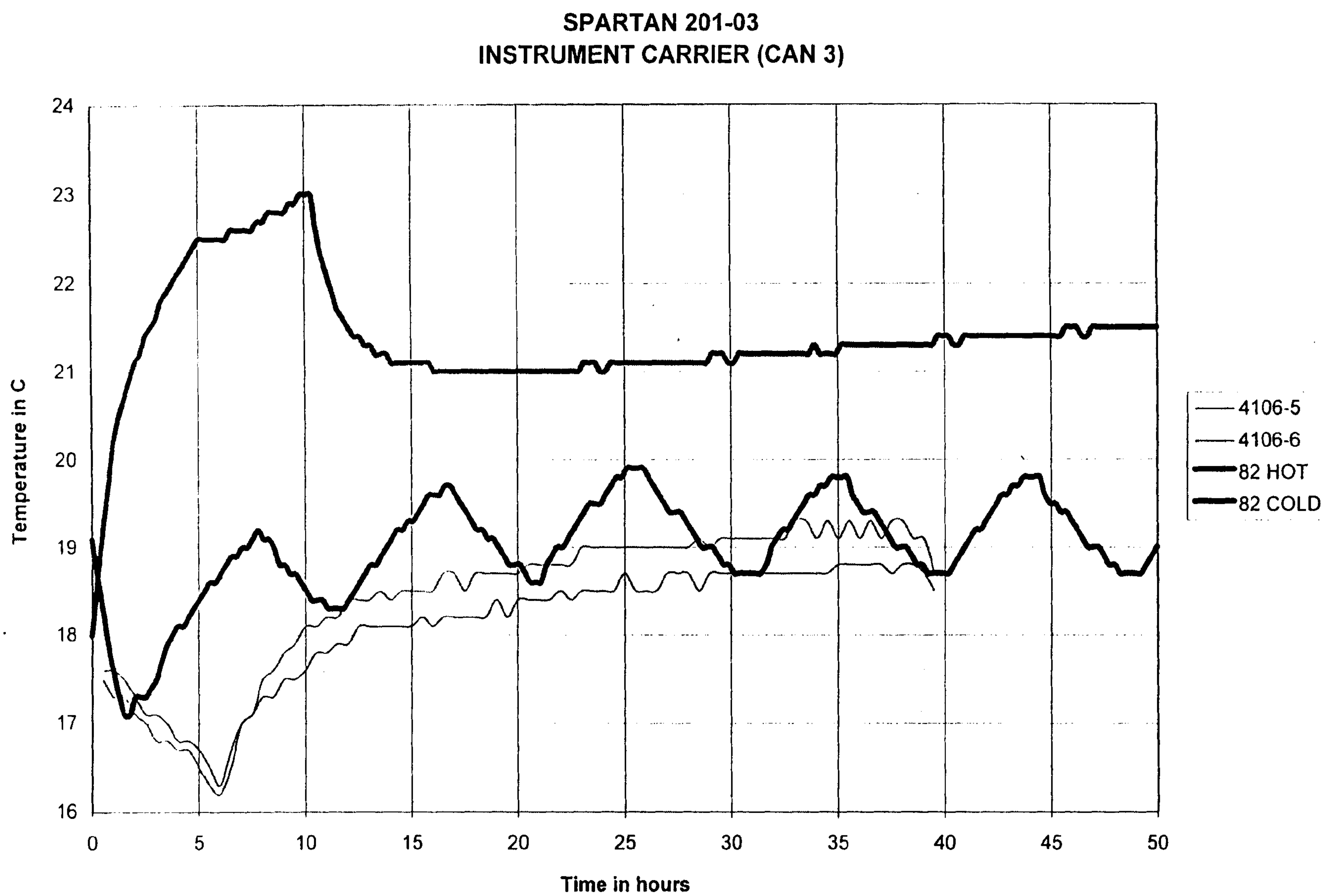
Spartan 201-03 Thermal Control System Performance Data

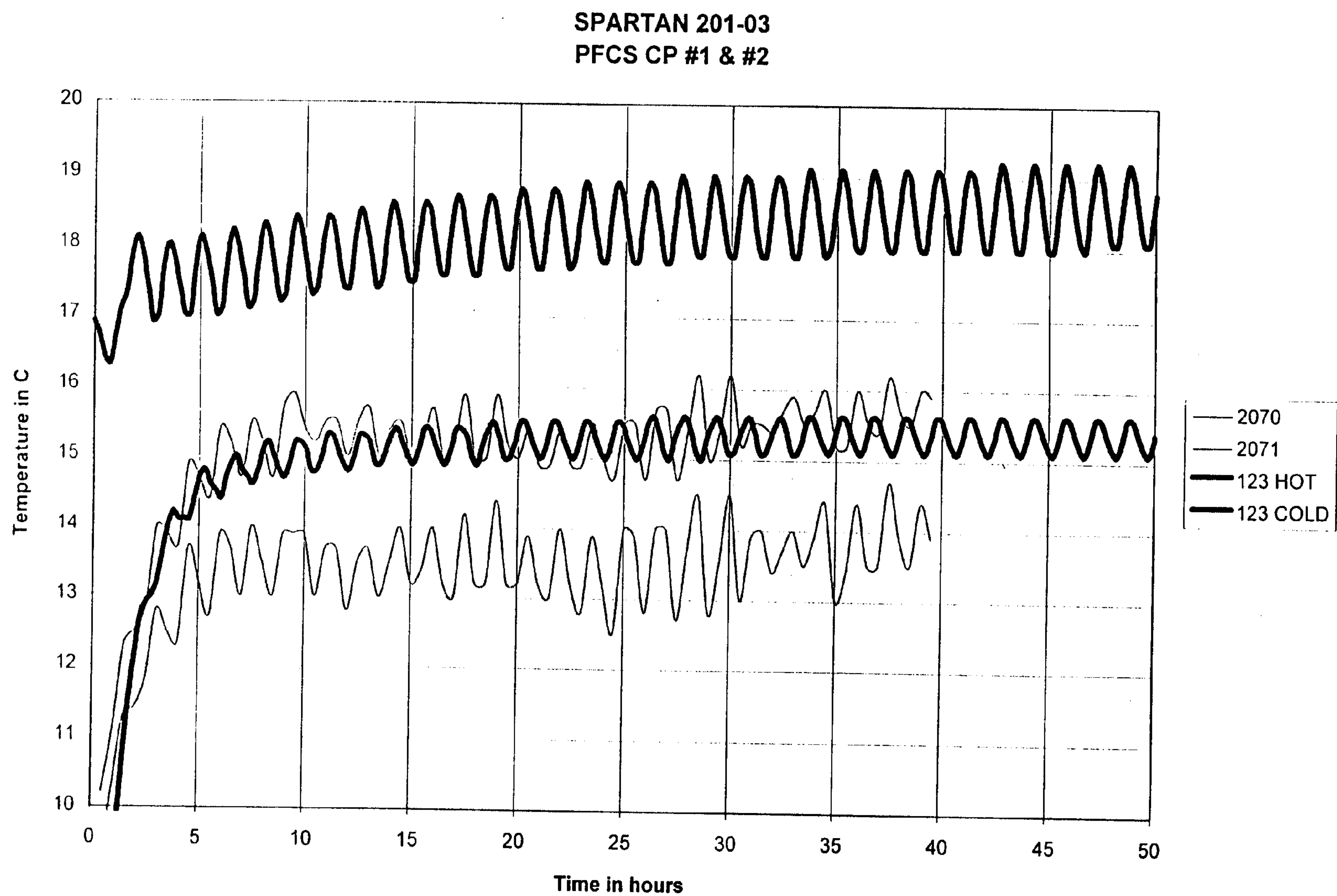
6 pages

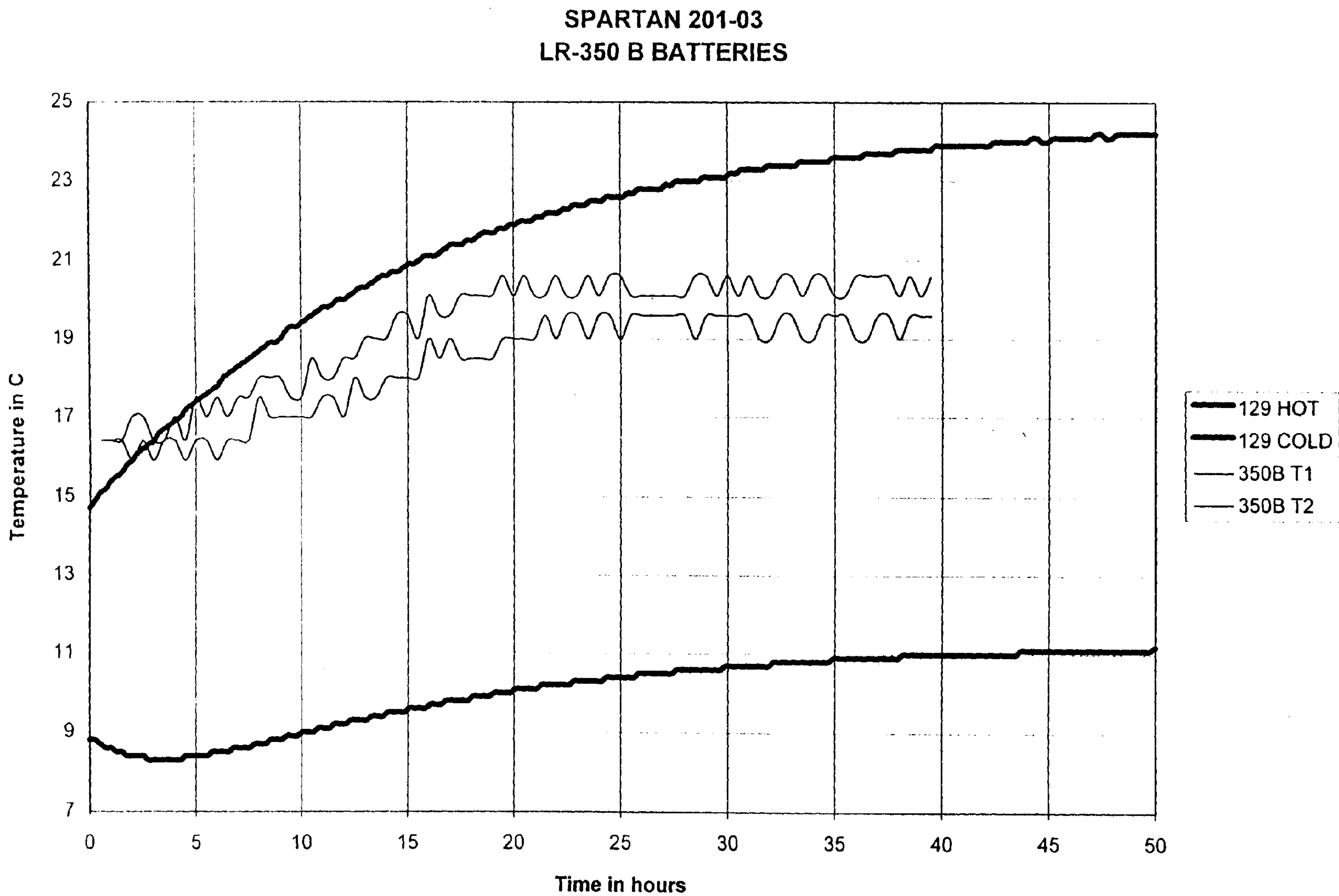
NOTE: All SP201 thermistors with a 4 digit designation are know to have a calibration error of approximately 4 ºC in the cold direction. This has *not been* corrected in the attached plots.
The thermistors with three digit designators are correctly calibrated.

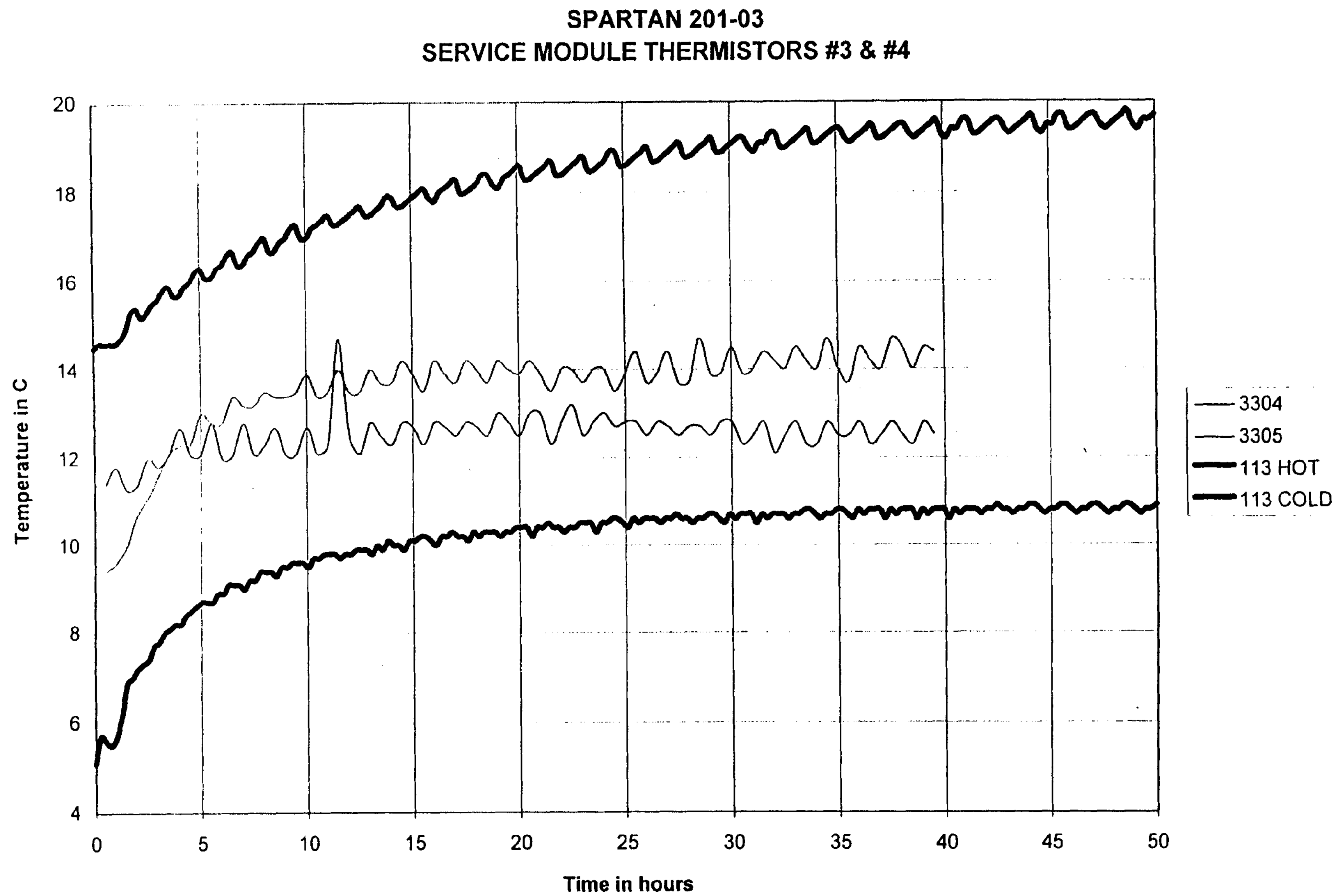


SPARTAN 201-03
INSTRUMENT CARRIER (CAN 1)
Temperature in C
24
22
20
18
16
14
12
10
0
5
10
15
20
25
30
35
40
45
50
Time in hours
4106-3
4106-4
80 HOT
80 COLD


SPARTAN 201-03
INSTRUMENT CARRIER (CAN 3)
Temperature in C
24
23
22
21
20
19
18
17
16
0
5
10
15
20
25
30
35
40
45
50
Time in hours
4106-5
4106-6
82 HOT
82 COLD


SPARTAN 201-03
PFCS CP #1 & #2
Temperature in C
20
19
18
17
16
15
14
13
12
11
10
0
5
10
15
20
25
30
35
40
45
50
Time in hours
2070
2071
123 HOT
123 COLD


SPARTAN 201-03
LR-350 B BATTERIES
Temperature in C
25
23
21
19
17
15
13
11
9
7
0
5
10
15
20
25
30
35
40
45
50
Time in hours
129 HOT
129 COLD
350B T1
350B T2


SPARTAN 201-03
SERVICE MODULE THERMISTORS #3 & #4
Temperature in C
Time in hours
3304
3305
113 HOT
113 COLD
20
18
16
14
12
10
8
6
4
0
5
10
15
20
25
30
35
40
45
50

SPARTAN 201-03
ACS COLD PLATE